

Transforming Our Energy Economy: the Role of Renewable Energy and Energy Efficiency



Dr. Douglas J. Arent
Director, Strategic Energy
Analysis Center
National Renewable Energy
Laboratory

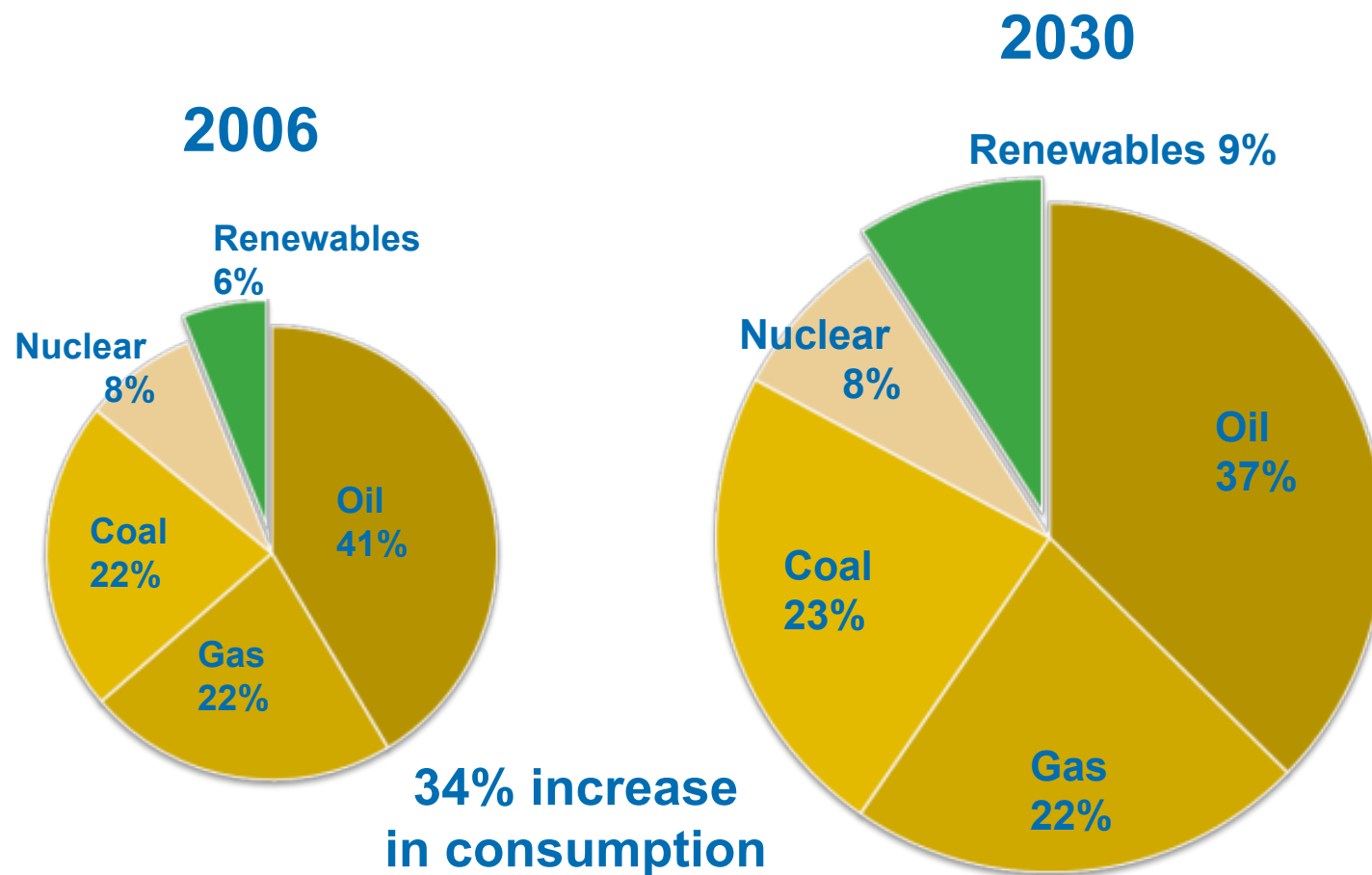
April 2009

Energy Solutions are Enormously Challenging



Must address all three imperatives

U.S. Energy Consumption and the Role of Renewable Energy

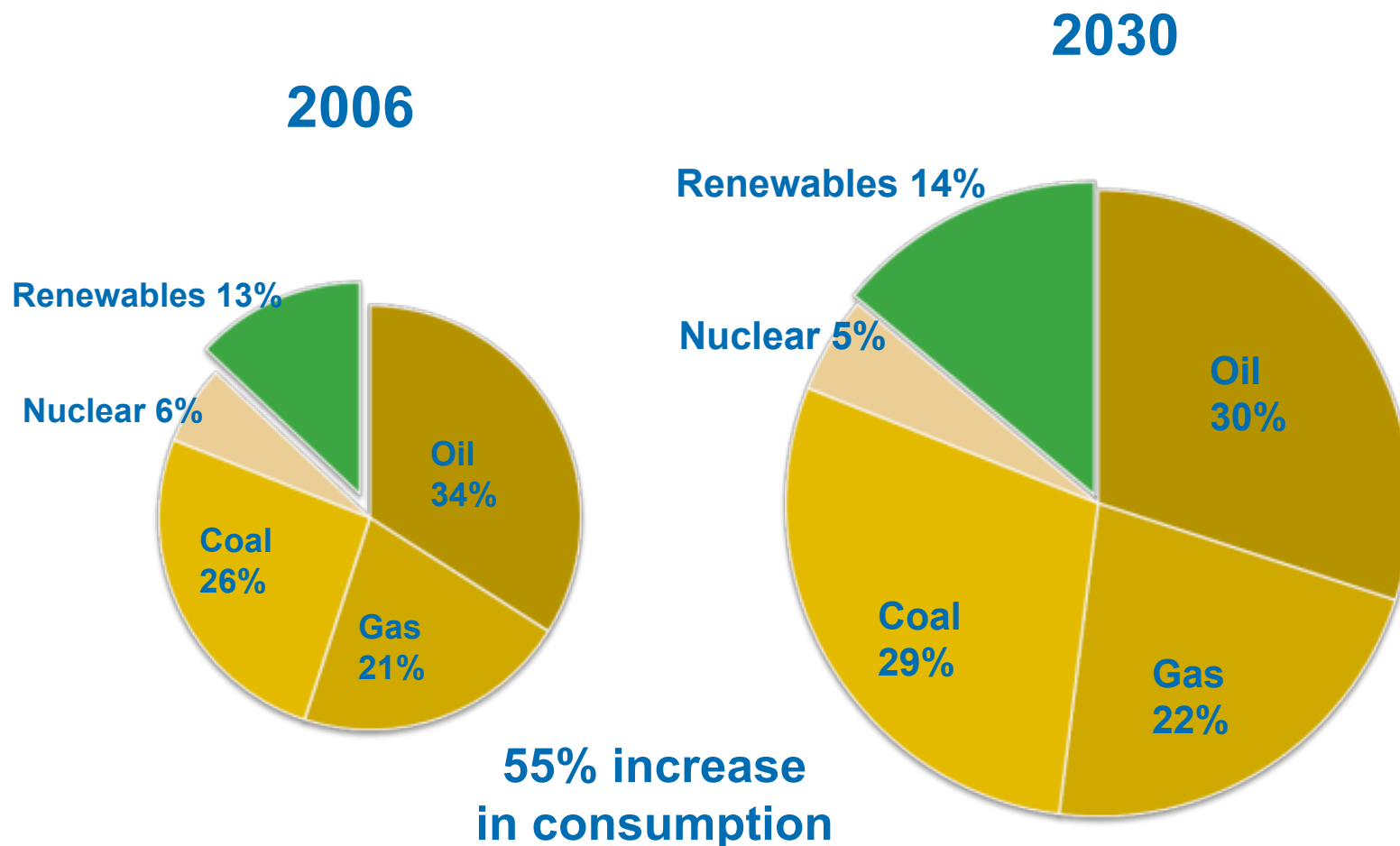


Units = Qbtu/year

Source: Energy Information Administration, *Annual Energy Outlook 2009 early release*, Table A1

<http://www.eia.doe.gov/oiaf/aeo/pdf/appa.pdf>

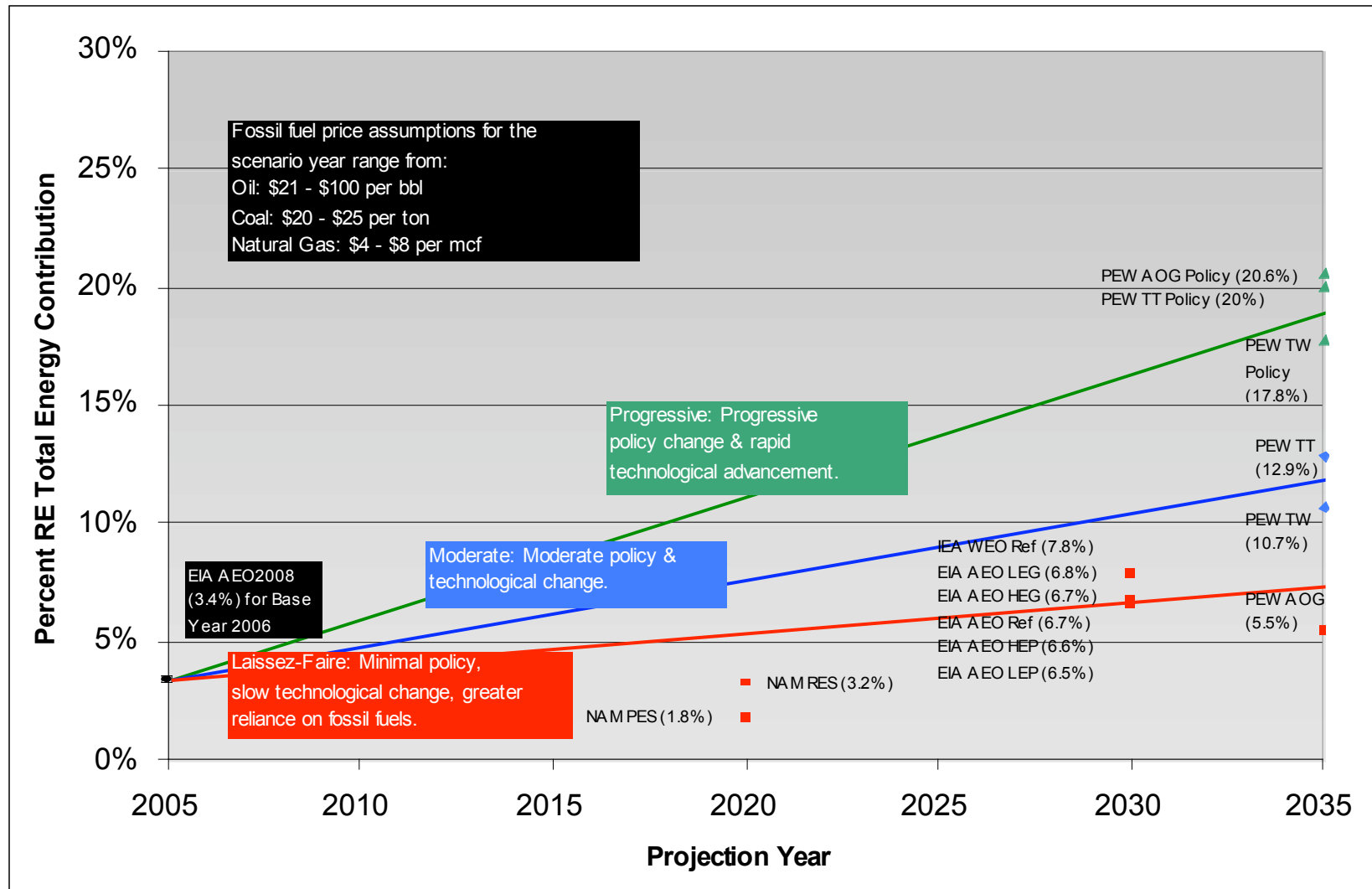
World Energy Supply and the Role of Renewable Energy



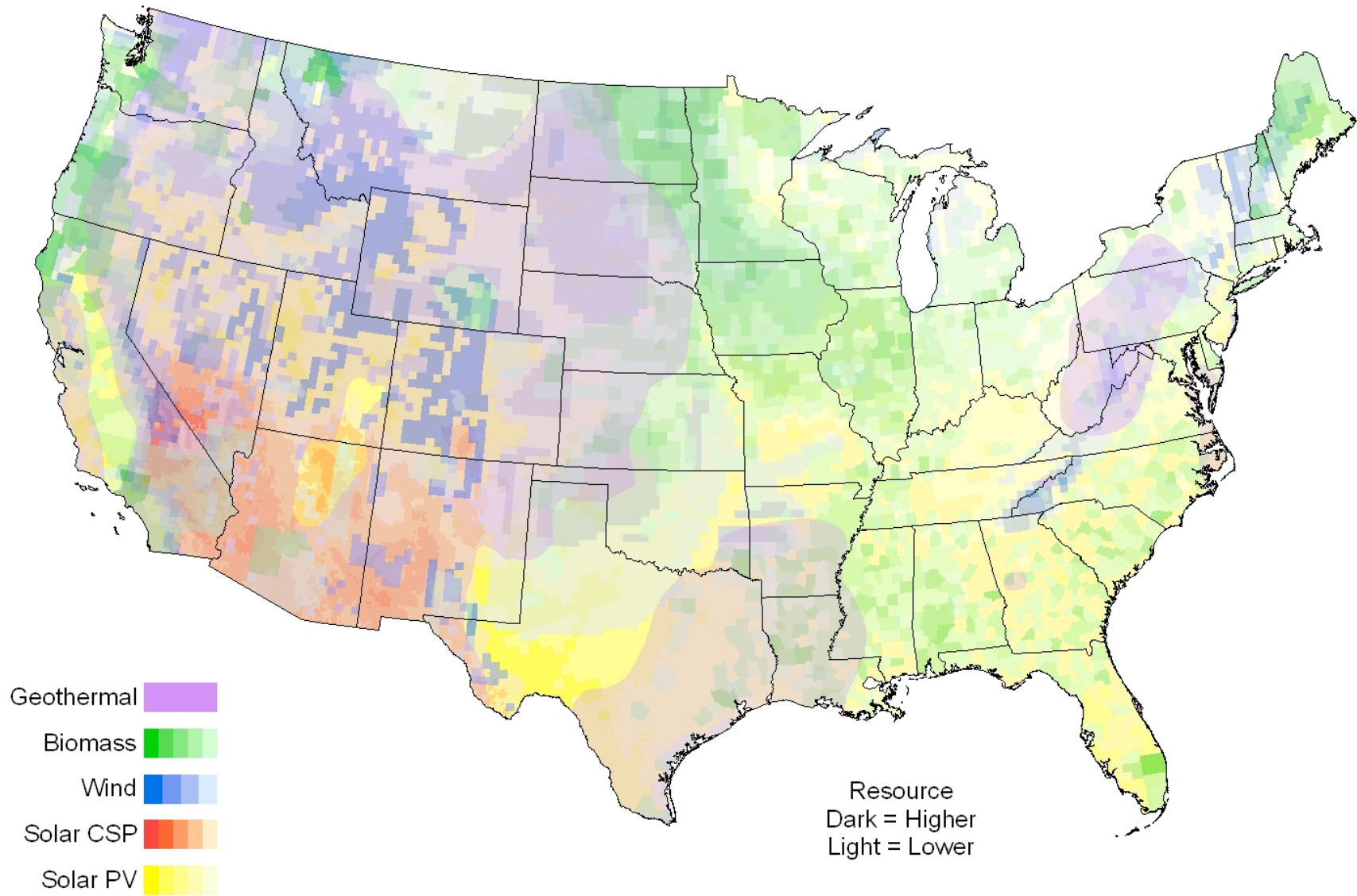
Units = Mtoe

Source: IEA/OECD, World Energy Outlook 2008, page 78, table 2.1

A Range of Possible Futures...

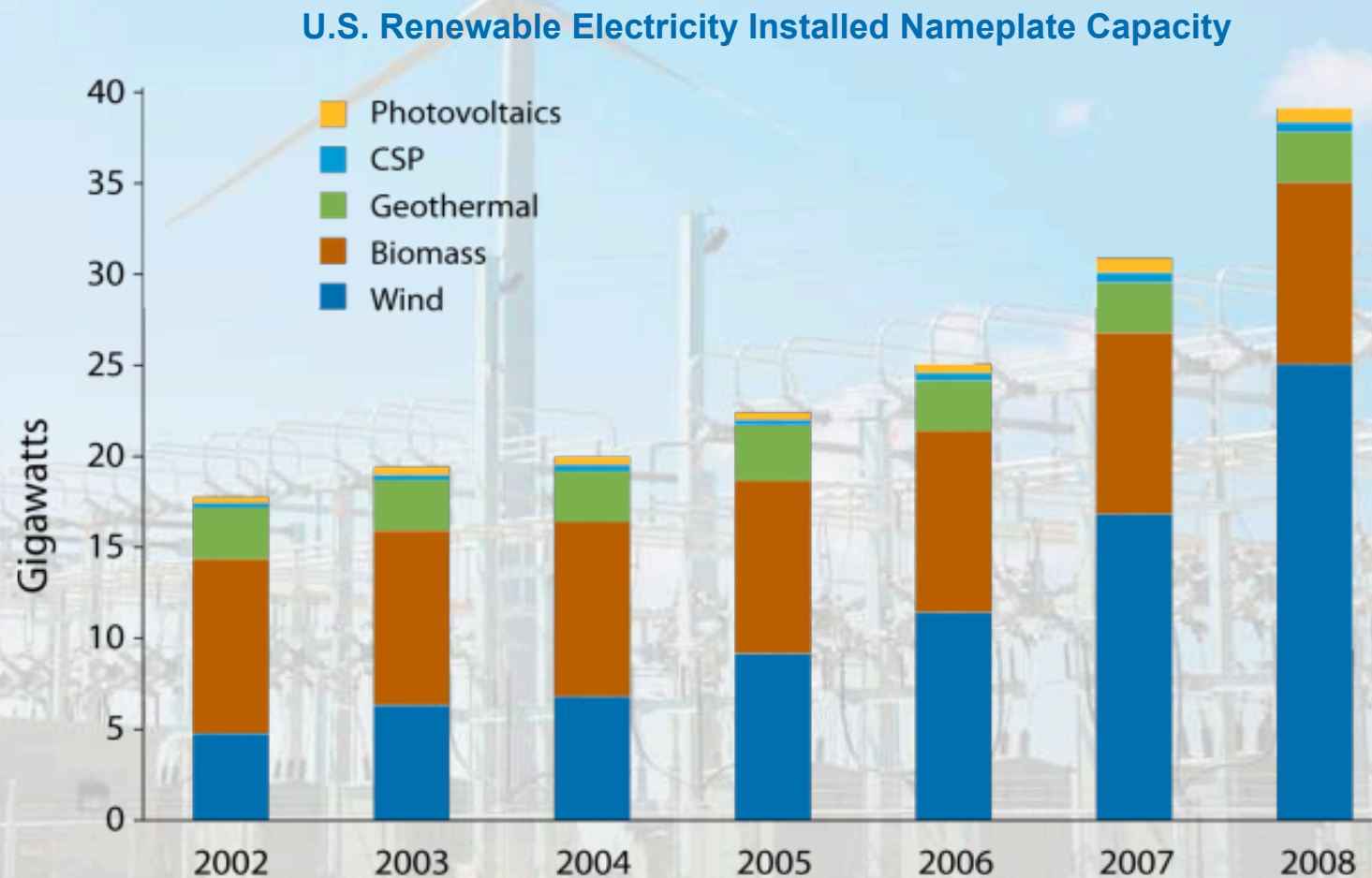


U.S. Renewable Resources



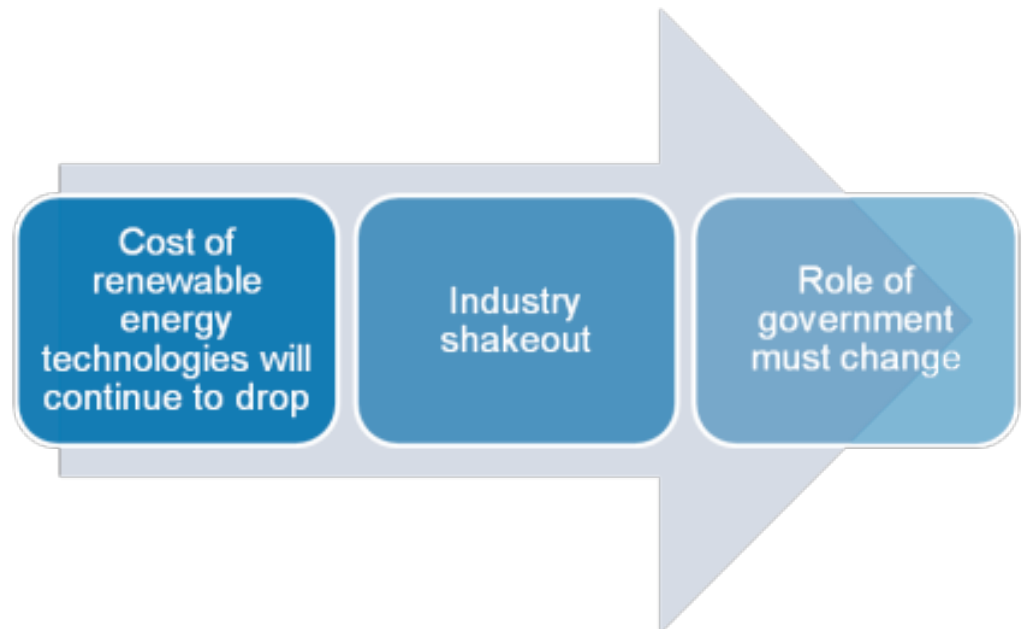
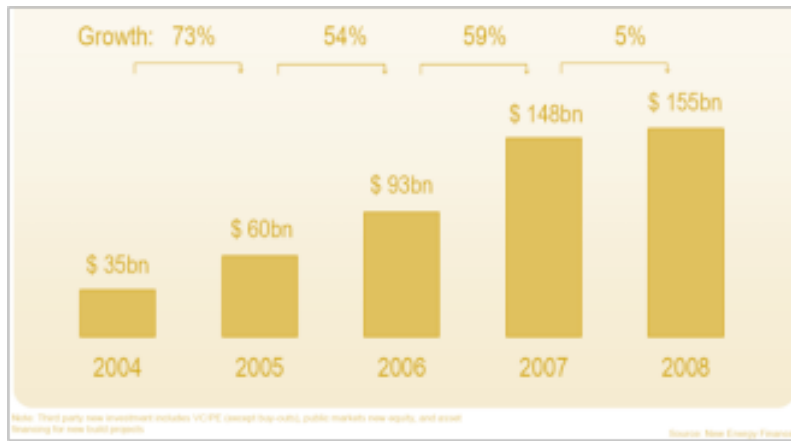
Economic Stimulus Through Harvesting Past Energy Investments

First Generation Clean Energy Technologies



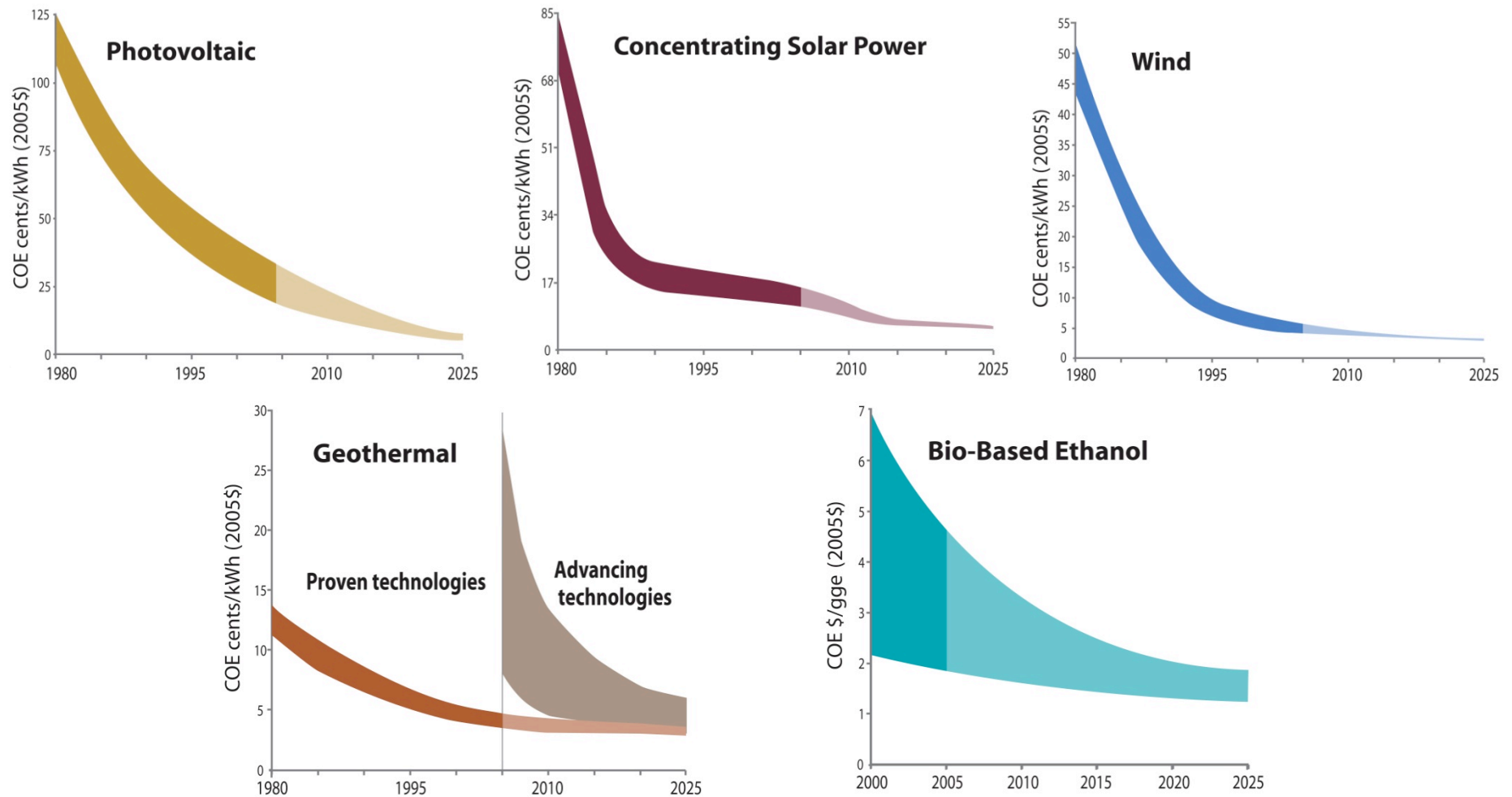
Source: EIA Annual Energy Outlook 2009 Early Release

Current Clean Energy Trends



Renewable Energy Cost Trends

Levelized cost of energy in constant 2005\$¹



Source: NREL Energy Analysis Office (www.nrel.gov/analysis/docs/cost_curves_2005.ppt)

¹These graphs are reflections of historical cost trends NOT precise annual historical data. DRAFT November 2005

Technology Development Programs

NREL R&D Portfolio



Efficient Energy Use

- Vehicle Technologies
- Building Technologies
- Industrial Technologies



Renewable Resources

- Wind and water
- Solar
- Biomass
- Geothermal

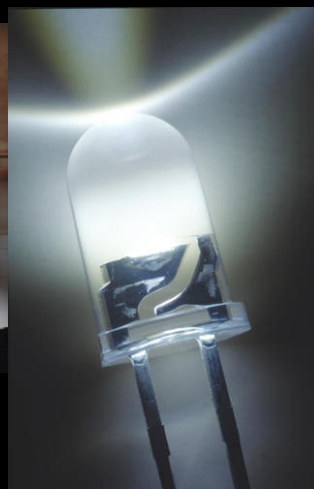
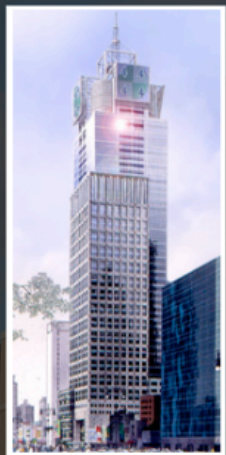


Energy Delivery and Storage

- Electricity Transmission and Distribution
- Alternative Fuels
- Hydrogen Delivery and Storage

Foundational Science and Advanced Analytics

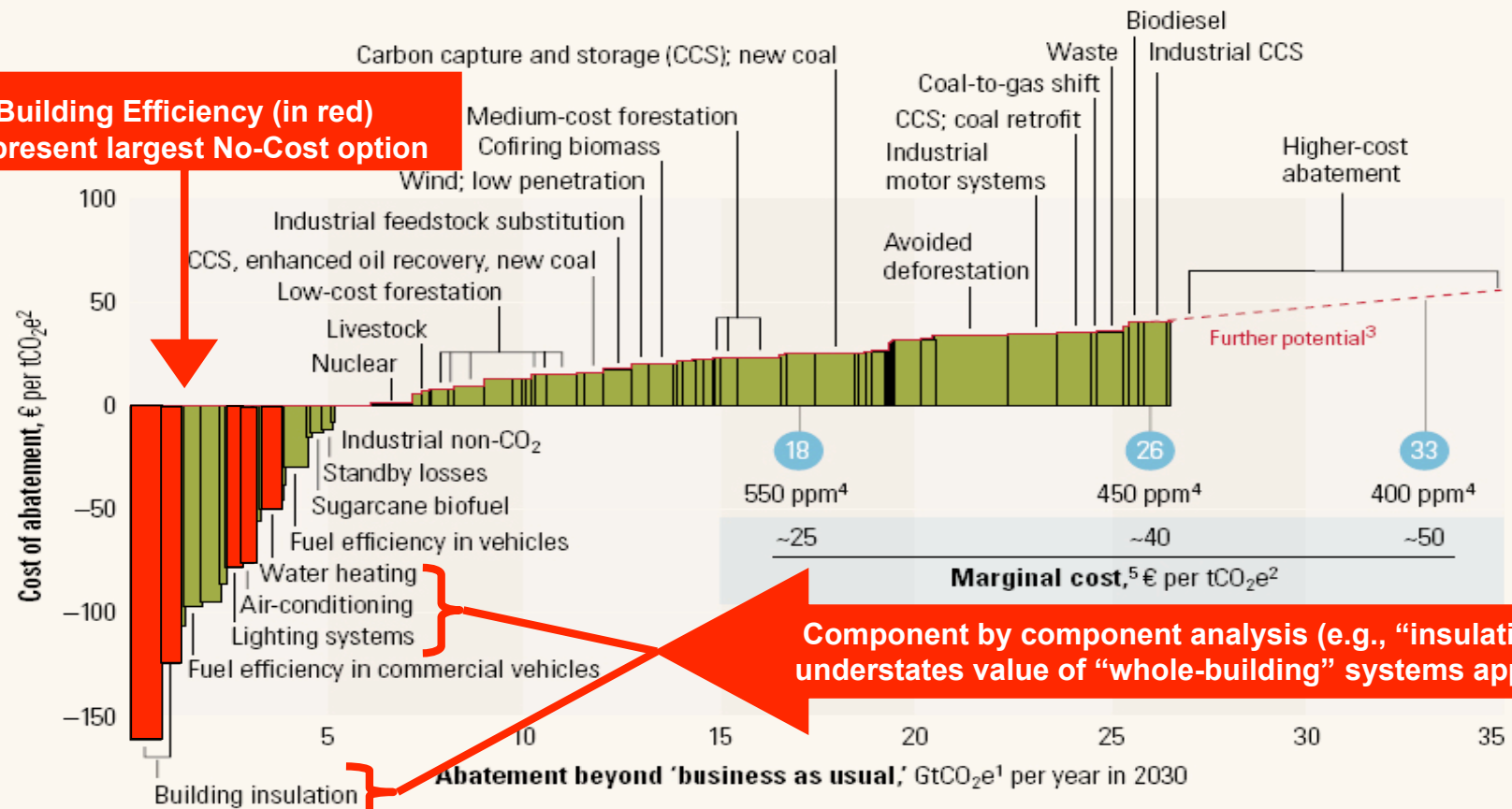
Energy Efficiency



Energy Efficiency Offers Low or No-Cost Carbon Reduction Options

Global cost curve for greenhouse gas abatement measures beyond 'business as usual'; greenhouse gases measured in GtCO₂e¹

● Approximate abatement required beyond 'business as usual,' 2030



¹ GtCO₂e = gigaton of carbon dioxide equivalent; "business as usual" based on emissions growth driven mainly by increasing demand for energy and transport around the world and by tropical deforestation.

² tCO₂e = ton of carbon dioxide equivalent.

³ Measures costing more than €40 a ton were not the focus of this study.

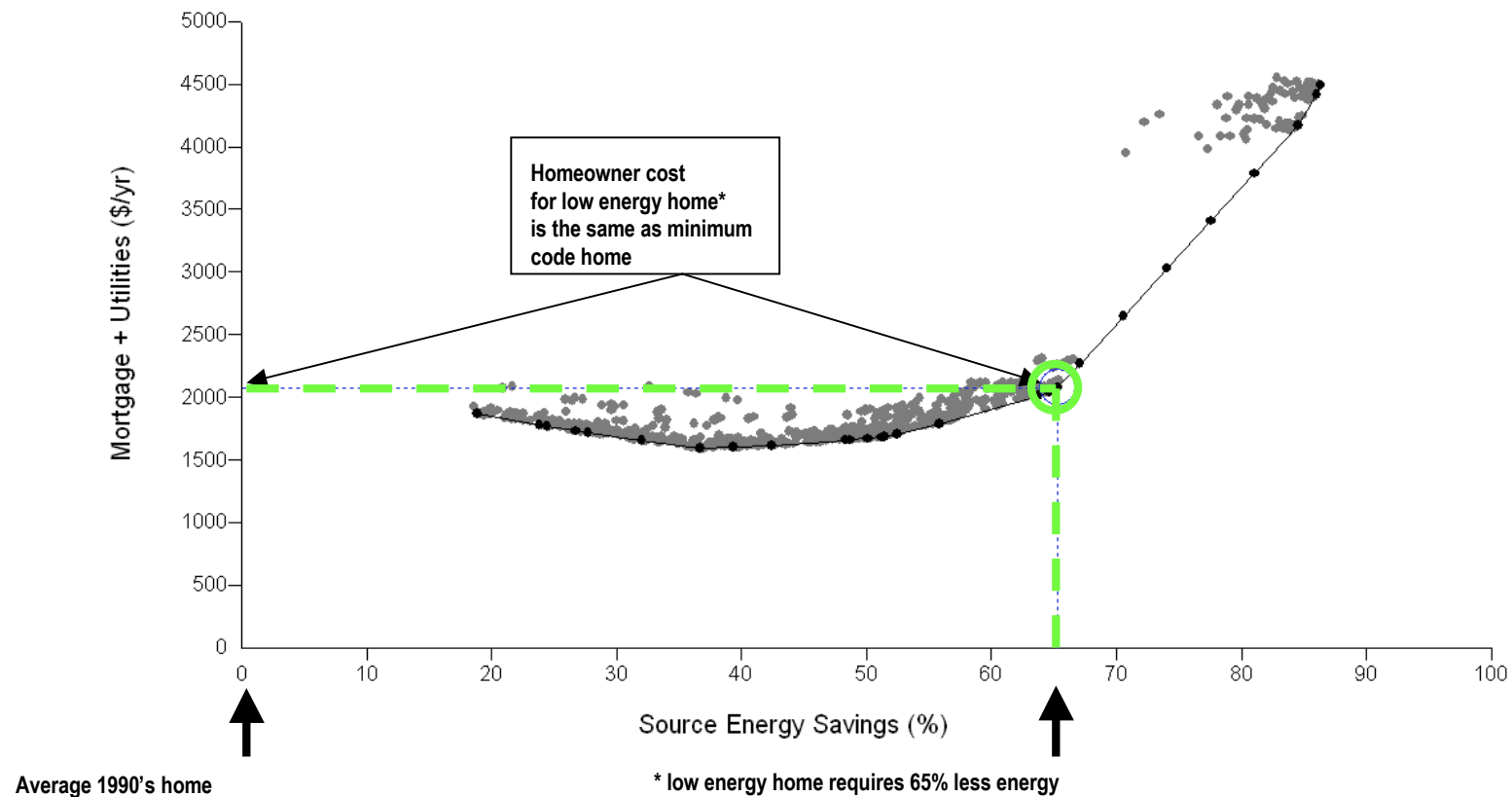
⁴ Atmospheric concentration of all greenhouse gases recalculated into CO₂ equivalents; ppm = parts per million.

⁵ Marginal cost of avoiding emissions of 1 ton of CO₂ equivalents in each abatement demand scenario.

Source: McKinsey Global Institute, 2007

Net-Zero Energy Homes That Are Cash Flow Neutral

• NREL Analysis using BEOpt software for Boulder, CO climate



Example taken from the "GEOS" Neighborhood. Courtesy of Wonderland Hills Development, Boulder Colorado

Buildings

Status U.S. Buildings:

- 39% of primary energy
- 71% of electricity
- 38% of carbon emissions

DOE Goal:

- Cost effective, marketable zero energy buildings by 2025
- Value of energy savings exceeds cost of energy features on a cash flow basis

NREL Research Thrusts

- Whole building systems integration of efficiency and renewable features
- Computerized building energy optimization tools
- Building integrated PV



April 10, 2008

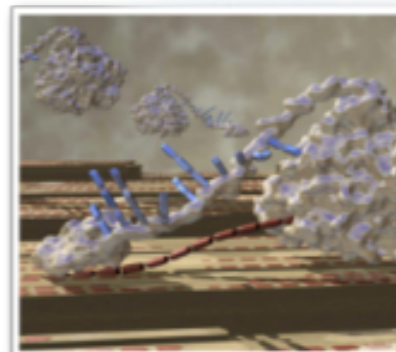
Renewable Electricity Supply



Technology Innovation Challenges Remain

The Next Generation

- Wind Turbines
 - Improve energy capture and decrease costs
 - Goal: 20% of U.S. electricity generation by 2030
- Biofuels
 - New feedstocks
 - Integrated biorefineries
 - Goal: 36B gal/year by 2022
- Solar Systems
 - Improved performance and reduced manufacturing costs
 - Nanostructures/new materials
 - Goal: 10% of U.S. electricity by 2025
 - New Supply Options
- New Renewable Supply Options
- More Efficient Buildings
- PHEV & High Efficiency Autos
- Smart Grid



NREL Research Thrusts

- Improved performance and reliability
- Advanced rotor development
- Utility grid integration

Photo credit: Megavind

Solar Research Thrusts

Photovoltaics

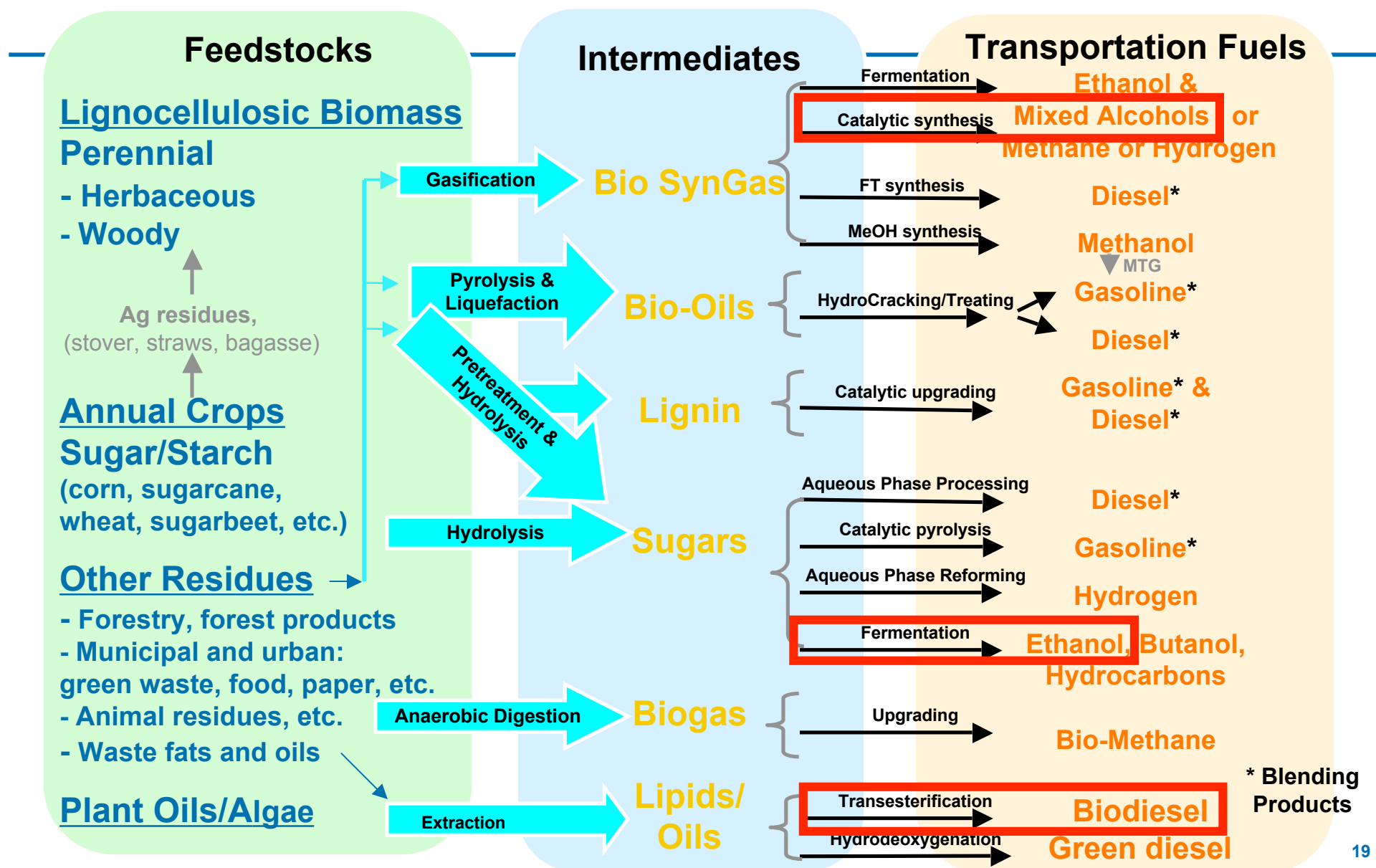
- Higher performance cells/modules
- New nanomaterials applications
- Advanced manufacturing techniques

Concentrating Solar Power

- Low cost high performance storage for baseload markets
- Advanced absorbers, reflectors, and heat transfer fluids
- Next generation solar concentrators

8.22-megawatt Alamosa, Colo., PV solar plant

Wide Range of Biofuel Technologies

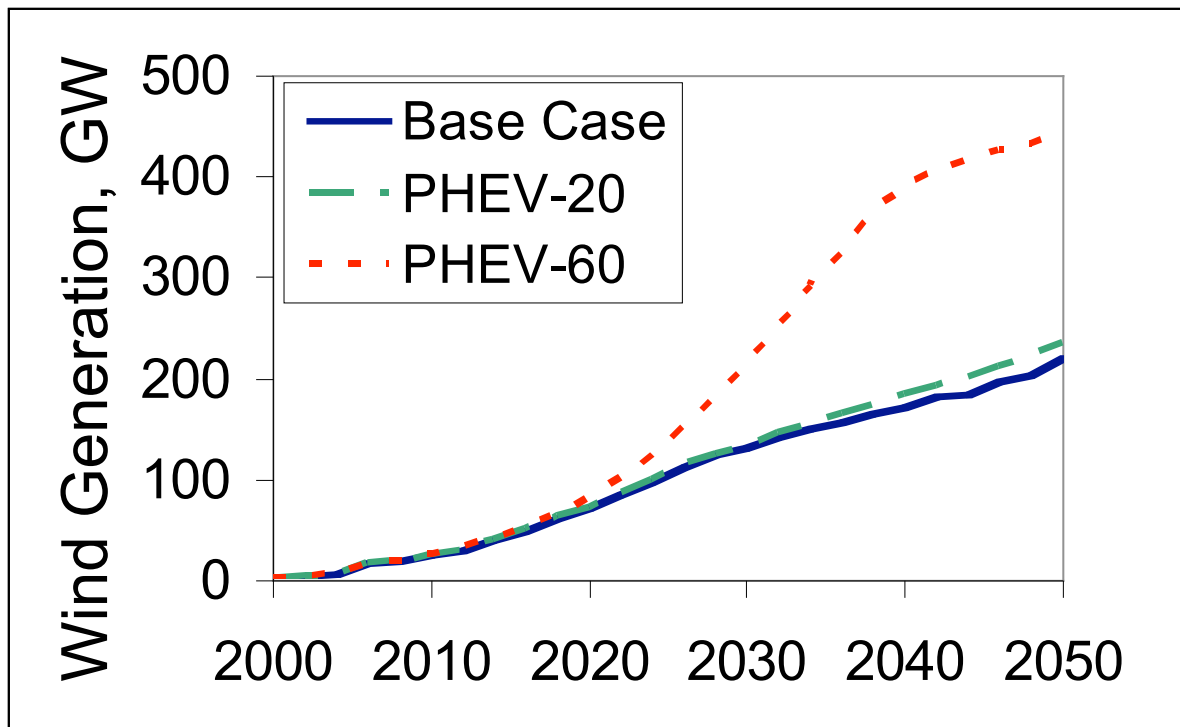


Advanced Vehicle Technologies



PHEVs/EVs and RETs

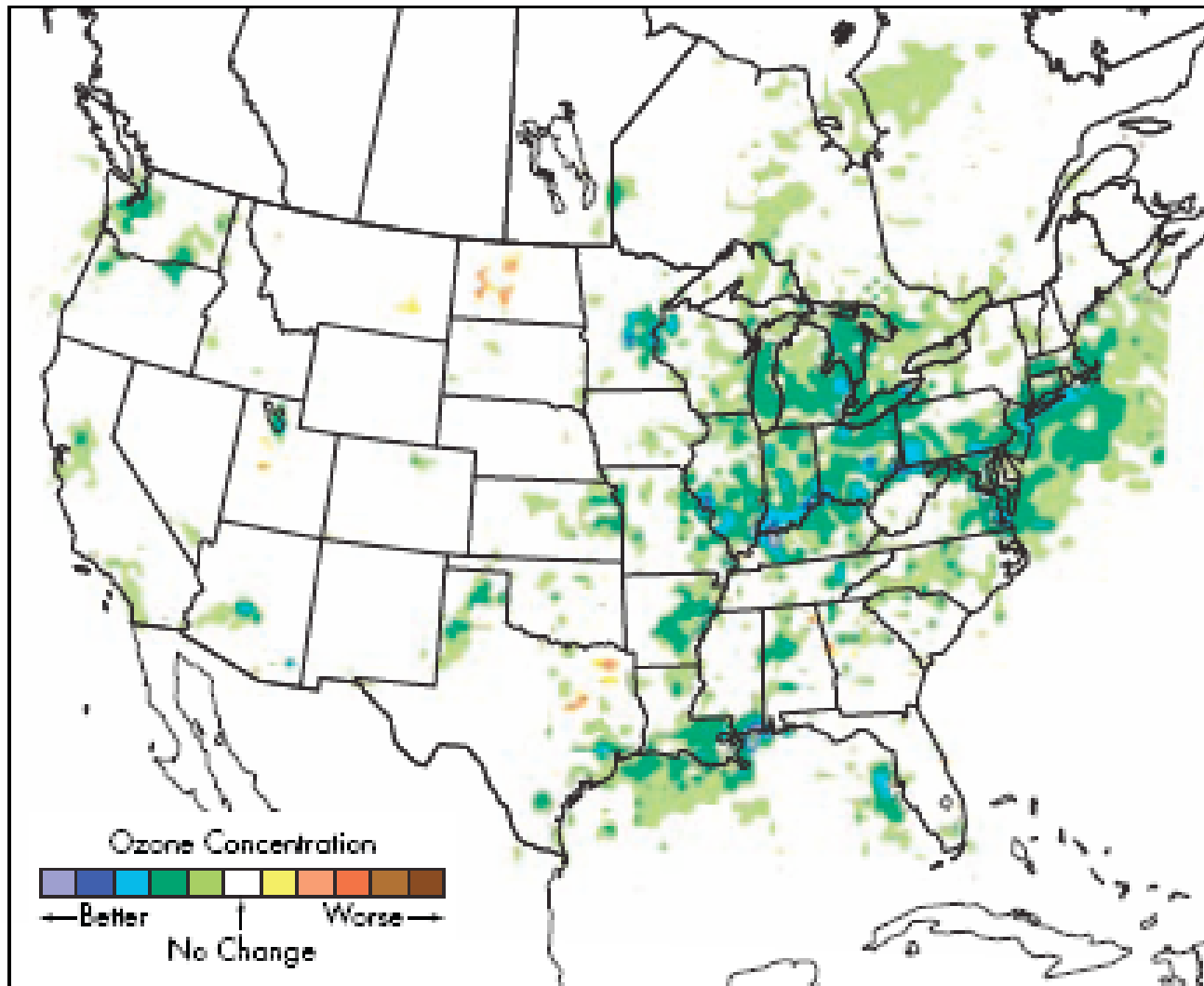
- Batteries and battery mgmt
- Smart Grid
- RTP/IT integration



Source: NREL Analysis



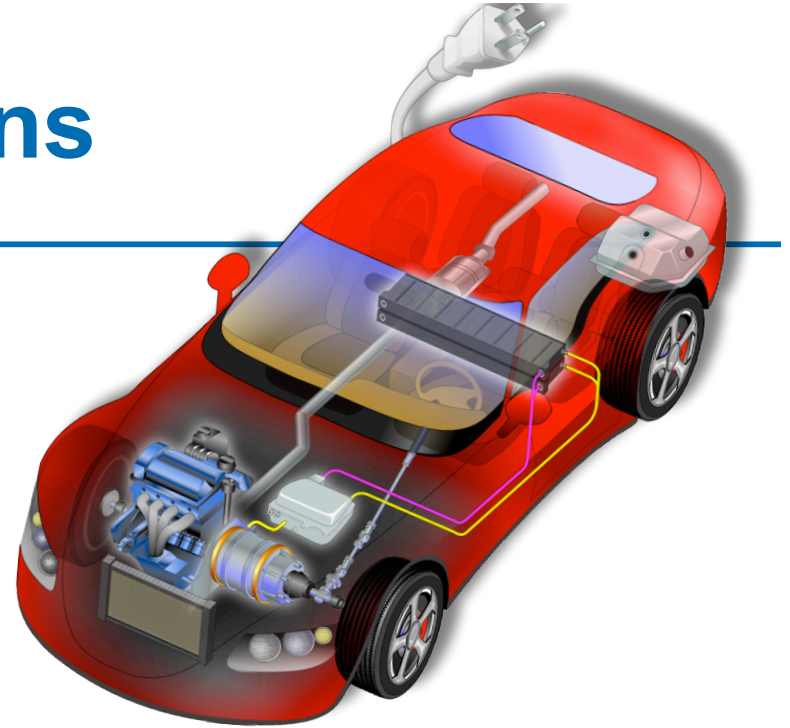
Possible CoBenefits



Source: EPRI, 2008

Challenges for Plug-Ins

- Improving batteries
 - Cost
 - Calendar and cycle life
 - Safety of Li-Ion
 - Cold temperature performance
 - Volume and packaging
- Reducing power electronics cost and volume
- Developing efficient chargers
- Standardizing plugs for charging
- Avoiding negative peak time charging impacts



Vision of Future Transportation

National Renewable Energy Laboratory • Concept - Ahmad Pesaran • Illustration - Dean Armstrong • NREL/GR-540-40698

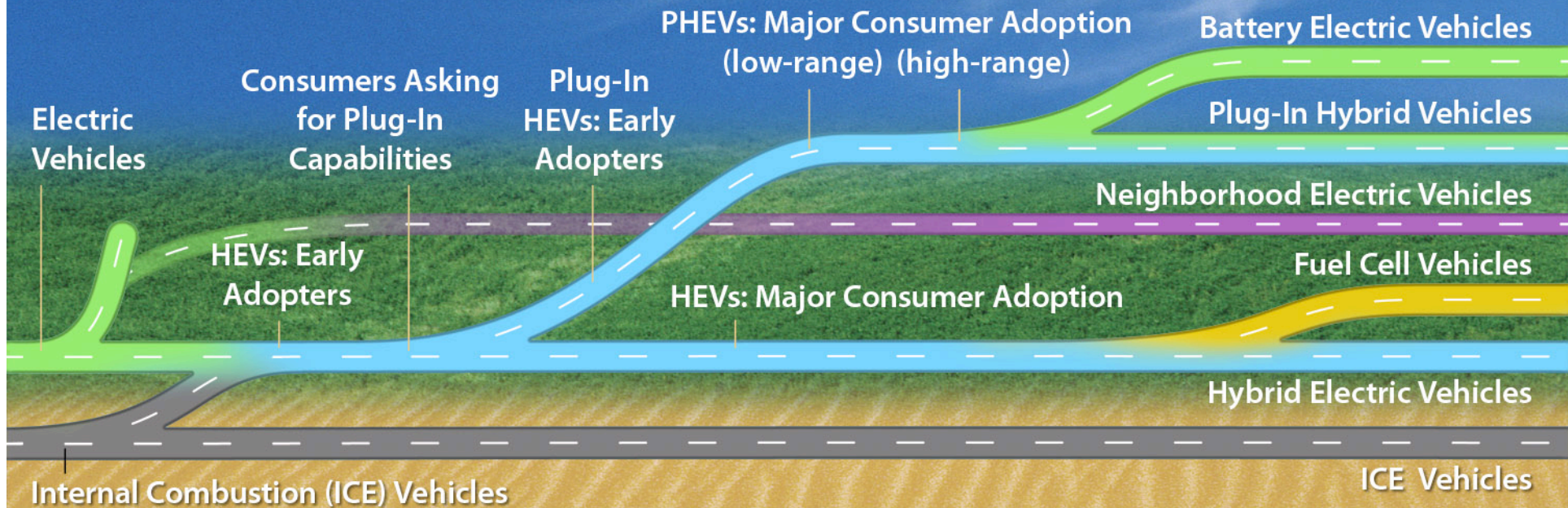


High Power ➤

Battery
Advancement

Affordable High Power, Acceptable High Energy ➤

Affordable High Energy ➤



Gasoline, Ethanol Blends ➤

Diesel, Biodiesel Blends ➤

B20, Biodiesel ➤

E85, Cellulosic Ethanol ➤

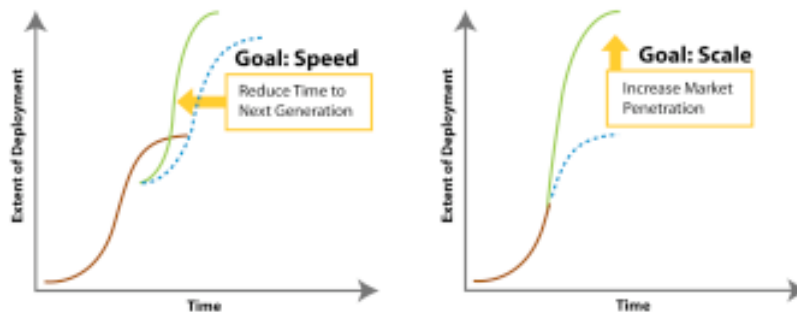
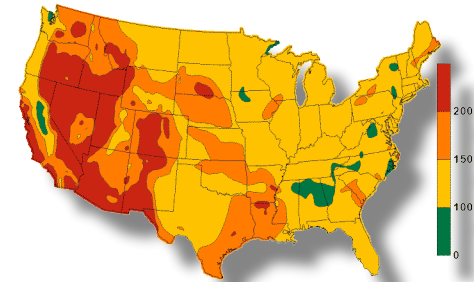
Electricity ➤

Hydrogen ➤

Fuels

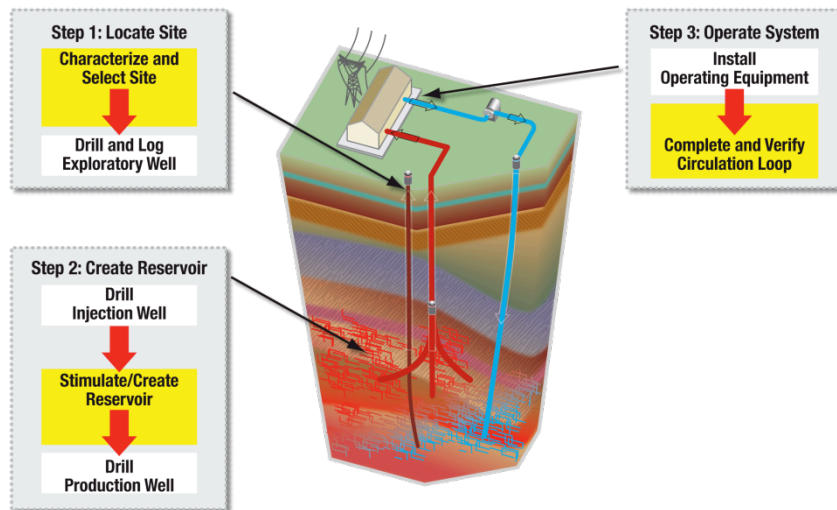
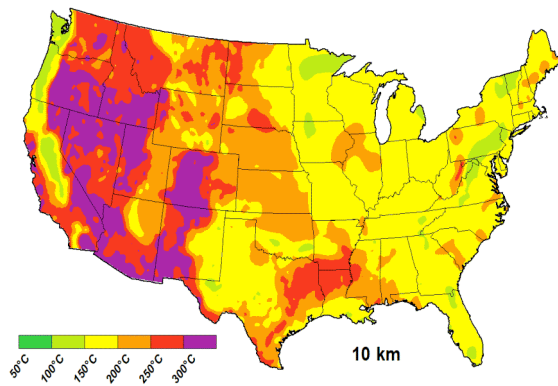
New Emerging Programmatic Areas

- Enhanced Geothermal Systems
- Ocean/tidal
- Smart Grid
- Focus on translational science
- New business models for commercialization and deployment
- Analysis evaluation/validation
- International cooperation

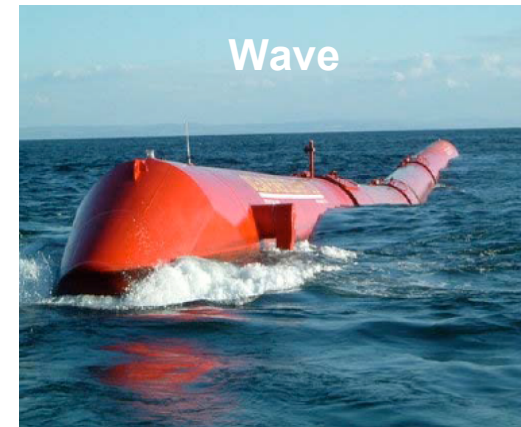


Evaluating Potential New Directions

Enhanced Geothermal Systems



Ocean Kinetic Energy



Tidal



Pelamis—Ocean Power Delivery

Verdant—Power RITE Turbine

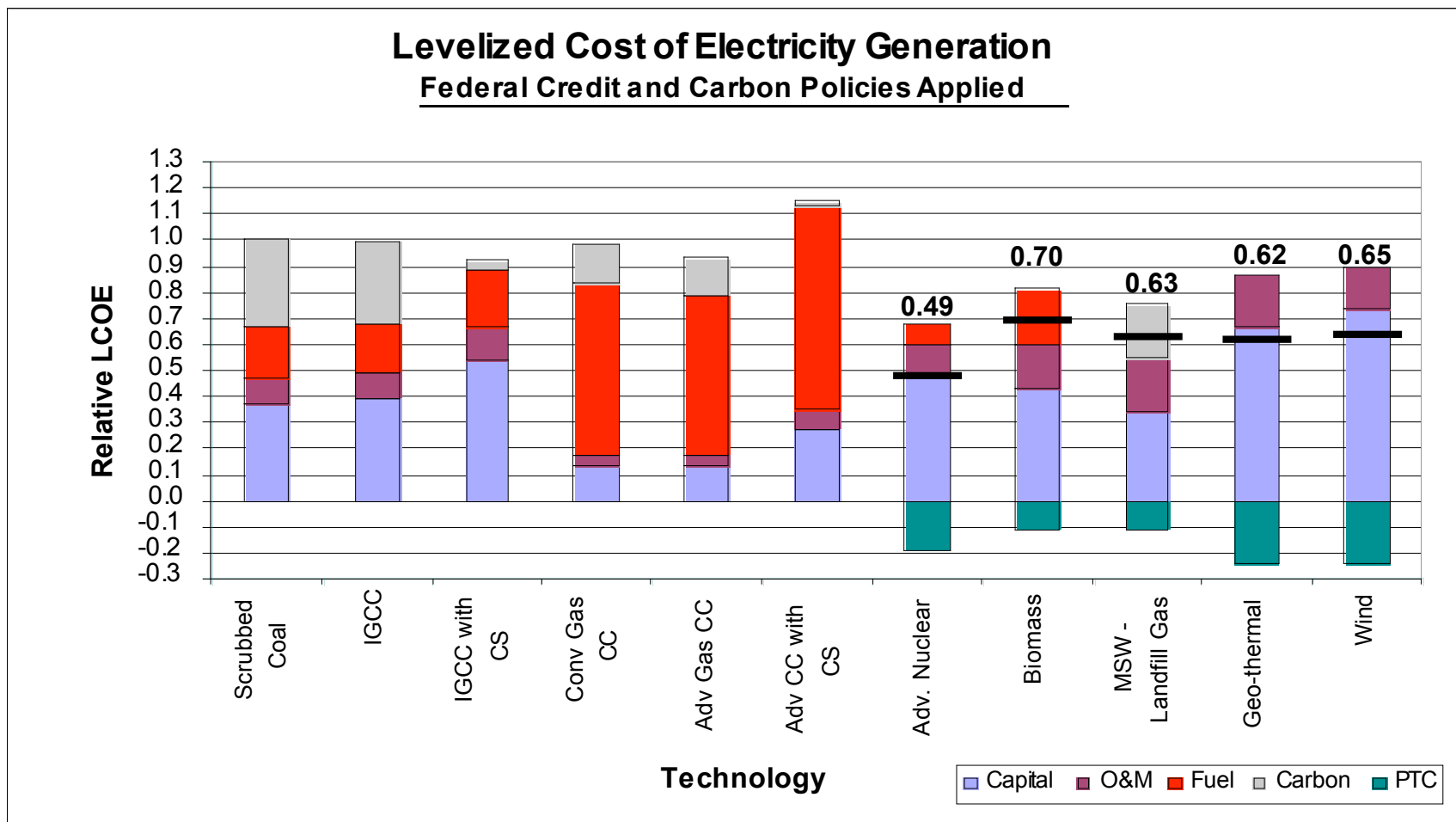
Looking Ahead with Optimism—American Recovery & Reinvestment



- Invest \$150B in alternative energy over 10 years
- Create green jobs with clean, efficient American energy
- Double production of alternative energy in three years – enough to power 6 million homes
- Upgrade the efficiency of more than 75% of federal buildings and two million private homes
- Transforming our economy with science and technology



Relative Nominal LCOE with PTC and Carbon Policy



Production and investment tax credits per EPACT 2005
 Carbon permit price: \$ 27/TCO₂
 Carbon sequestration assumed to eliminate 90% of carbon emissions

Numerical values represent total LCOE after tax credit applied

Getting to “Speed and Scale” for Renewable Energy – Key Challenges

Implementing Renewable Gigawatts at Scale



BARRIERS

- Cost
- Reliability
- Infrastructure
- Dispatchability

Displacement of Petroleum-Based Fuels



BARRIERS

- Cost
- Life cycle sustainability
- Fuels infrastructure
- Demand and utilization

Reducing Energy Demand of Buildings, Vehicles, and Industry



BARRIERS

- Coordinated implementation
- Valuing efficiency
- Cost
- Performance and reliability

Achieving the Potential Requires Sustained Effort





NREL

National Renewable Energy Laboratory

Innovation for Our Energy Future



Visit us online at www.nrel.gov

Operated for the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy by the Alliance for Sustainable Energy, LLC